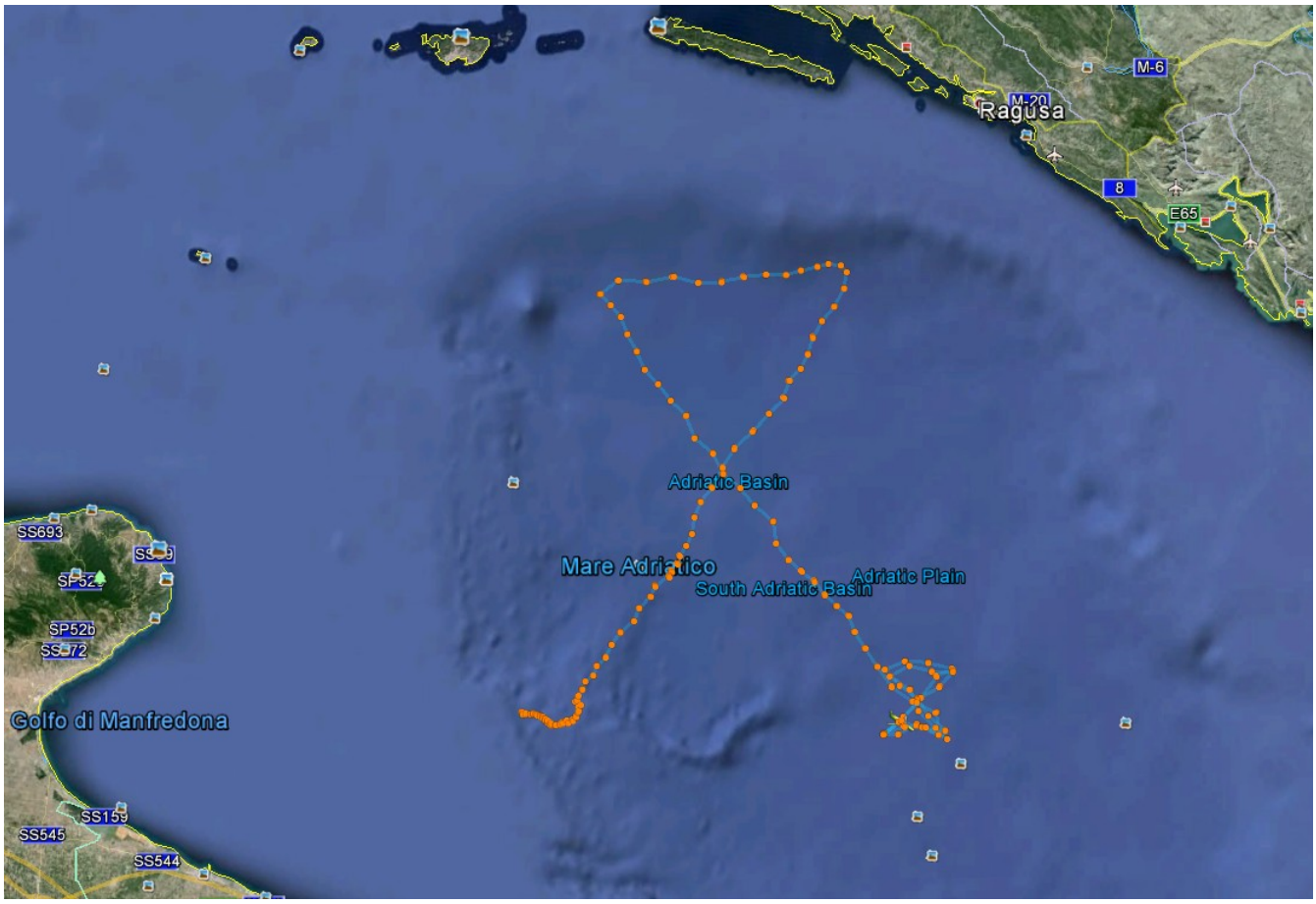

PRELIMINARY DATA ANALYSIS FROM SEAGLIDER IN CONVEX14 MISSION

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Approved by: …….

Dr. Paola Del Negro

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1. Introduction

The present report analyzes the iRobot SeaGlider AMERIGO data from the CONVEX14 mission. During that mission, the glider performed 128 dives (meaning 256 downcast and up-cast profiles), starting on 15/02/2014 at 14:24:24 UTC and finishing on 06/03/2014 at 03:06:58 UTC.

The mission took place in the South Adriatic Pit (SAP), with the aim to observe the open ocean convection that produces Adriatic Deep Water (ADW). This water represents the main component of the Eastern Mediterranean Deep Water (EMDW) and it has special characteristics such as temperature around 13.3 ^{o}C and salinity around 38.6 PSU and its density can be around 29.2 kg/m^{3} (Gacic et al, 1998, Pollak 1951). The glider was deployed on 15/02/2014 at 14:24:24 UTC at 41° 36' 12.96" N and 17° 1' 4.8" E and its trajectory is shown in Fig. 1. A semicircular orbit path was initially followed (black points), while it was fine tuned for the sea water density (i.e. specific parameters were set in order to optimize the glider flight). After this first part, the glider headed northeastward (red part). Then, it was steered westward

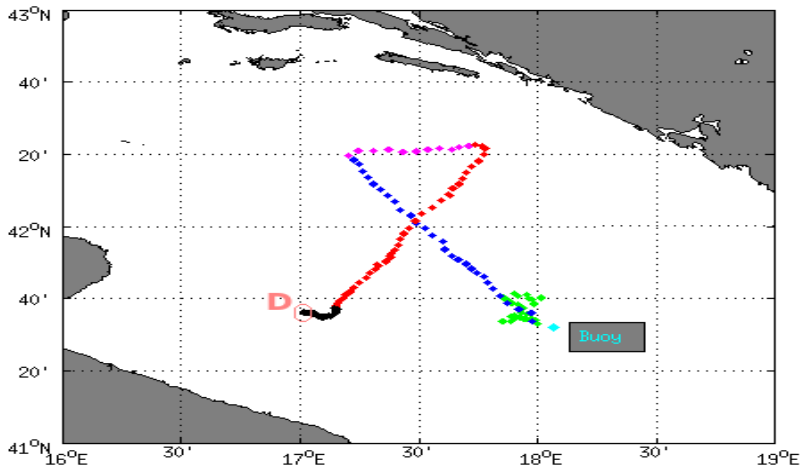


Fig. 1: Glider trajectory during the CONVEX14 mission. The letter D indicates to deployment position.

(purple part), and finally southeastward (blue part). The mission ended in a half times a 'butterfly' pattern (green part) near to the OGS E2M3A buoy (marked with light blue color). The instrument was recovered at 41° 33' 38.88" N and 17° 51' 8.2794" E on 06/03/2014 at 03:06:58 UTC.

After the recovery, the glider was sent to the factory for calibration. The conductivity sensor was found cracked. The 'post cruise' evaluation of the sensor performed by Sea-Bird demonstrates that the damaged conductivity cell caused a shift in the recorded values. A correction was applied on the conductivity raw data and salinity and density were recomputed. More informations about this procedure is reported in Gerin and Kokkini (2015).

2. Glider data

The Glider Amerigo is equipped with a Sea-Bird pumped CTD, which measures sea temperature, pressure and salinity (derived by conductivity), an Aanderaa Optode 4330 oxygen sensor that measures oxygen and a WetLab BB2FL-VMT that measures chlorophyll fluorescence and back-scattering. Unfortunately this last sensor failed during the deployment and was not used during that mission.

The data may include “spikes” since they have not undergone a quality control procedure, only a first level 'cut-off' of extreme values was performed. All the data were plotted along track with a linear interpolation in time for longitude and latitude values (Fig. 2 to Fig. 5).

For a better description of the data, we separated the glider data into the different parts (transects), marked with different colors in Fig.1. For each part, we produced scatter plots of temperature, salinity, density and oxygen.

3. Plots along Track

To plot the data along the glider track, the latitude and longitude have been interpolated (since GPS data are available only while the glider is at surface) using the time recorded by the CTD sensor while the glider was underwater.

All the data were plotted as a 3-D scatter plot, with latitude in y axes, longitude in x axes and depth (in meters) in z axes. The same color coding was adopted for each parameter in the different parts.

The thresholds that we set for each parameter are as follows: the temperature range from 13.28 to 15.52 ^{o}C, the salinity from 38.55 to 38.93 PSU, the density from 28.65 to 29.26 kg/m^{3}, and the dissolved oxygen from 4.8 to 6.2 ml/l. Values over or under those limits were considered as spikes.

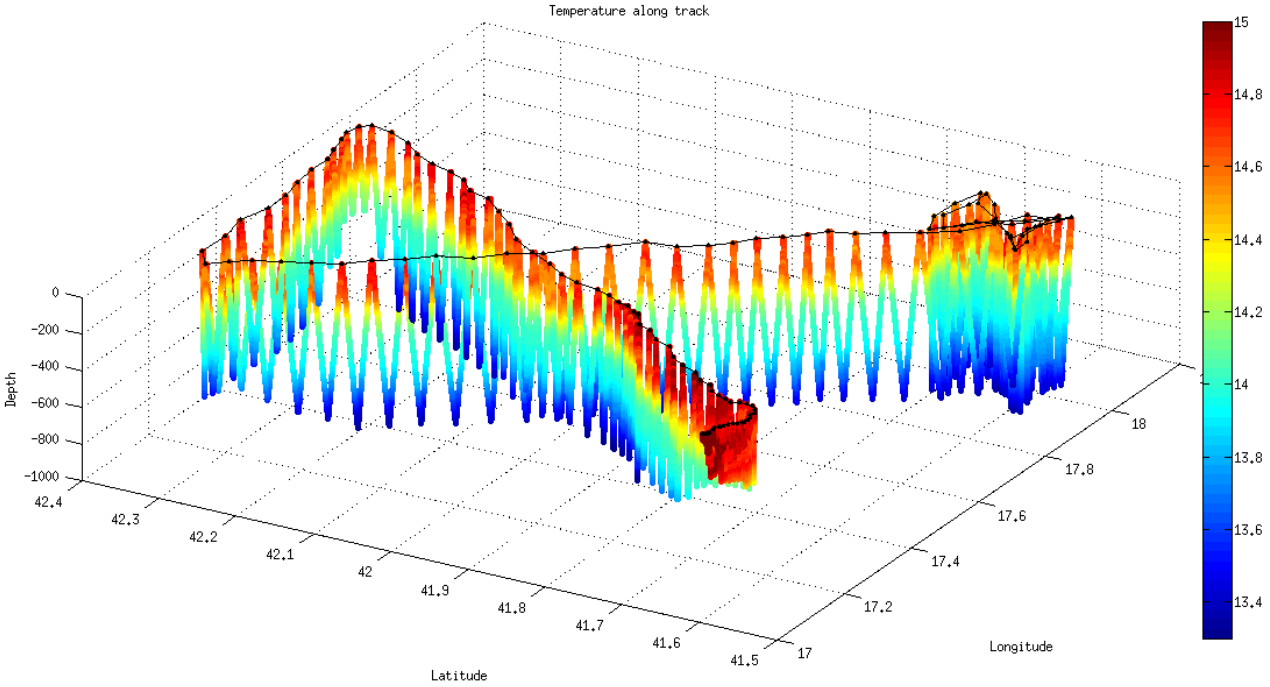


Fig. 2: Temperature (°C) along track. The black line represents the surface trajectory of the glider.

Fig. 2 depicts the temperature during the entire mission. The temperature varies from 15 ºC at the surface waters to 13.3 ºC in deep waters. The warmer surface waters are close to the Italian coasts and the colder around the southeast 'butterfly' transect.

From 200 to 500 m depth, the temperature varies from 14.2 to 13.9 ºC and from 500 m to almost 1000 m depth the temperature is more stable along track and ranges between 13.9 and 13.3 ºC.

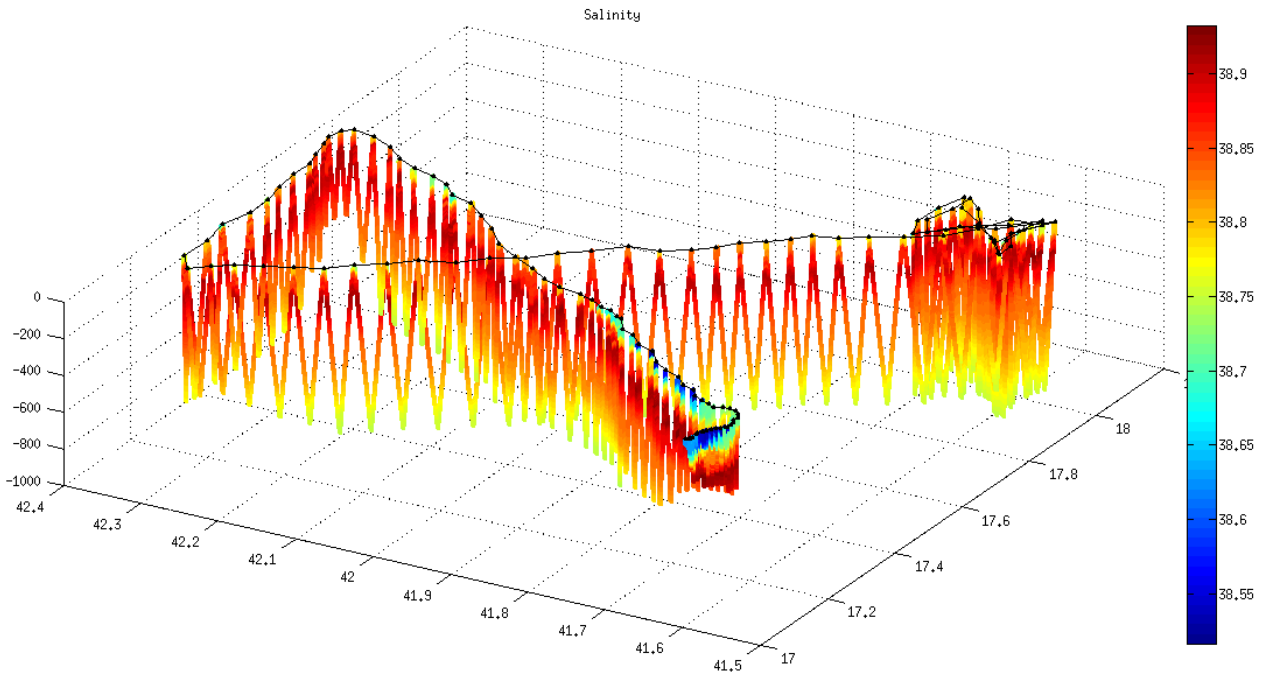


Fig. 3: Salinity (PSU) along track. The black line represents the surface trajectory of the glider.

During the entire mission, the salinity (Fig. 3) varies from 38.55 to 38.93 PSU. The lower salinity was measured in the surface waters near to the Italian coasts. Most of the surface waters are characterized by a salinity around 38.8 PSU, while near to the Italian coast (first and second transect) there are filaments of low saline waters (around 38.55 PSU).

The layer of the most saline water reaches 38.9 PSU and is located between 200 and 300 m depth. Under that layer and down to 500 m, the salinity decreases, ranging from 38.8 to 38.75 PSU. In the deepest layers (to almost 1000 m), the salinity reaches 38.7 PSU.

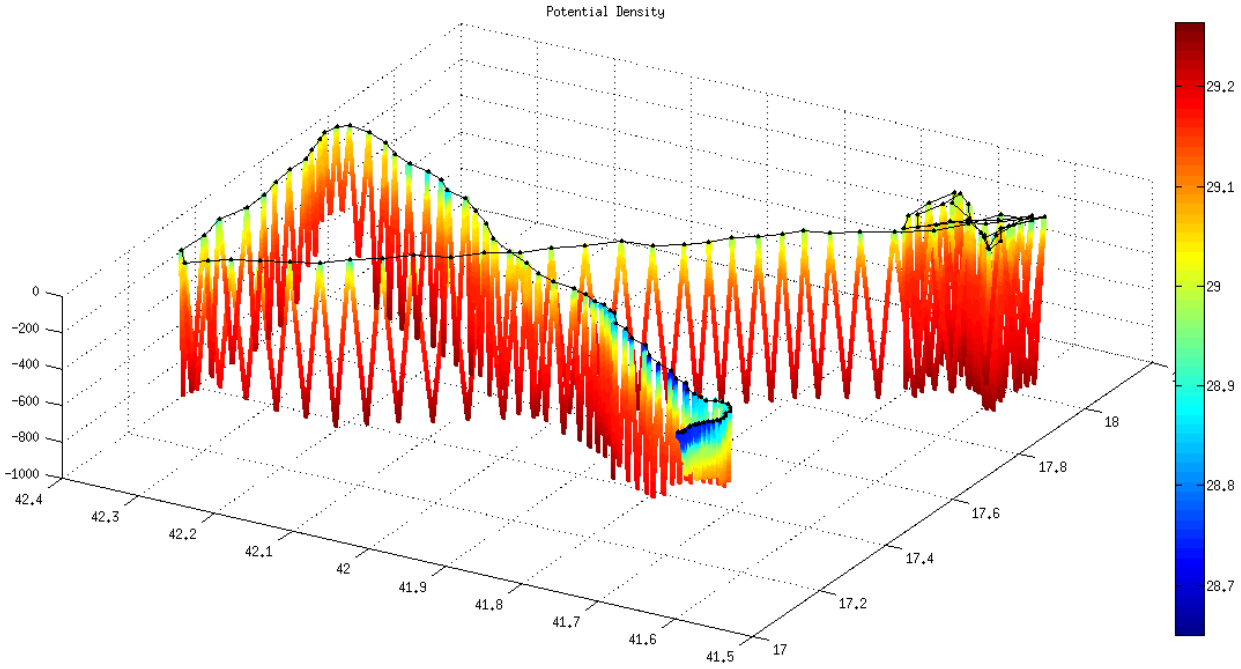


Fig. 4: Potential density (kg/m^3) along track. The black line represents the surface trajectory of the glider.

Fig. 4 shows the density during the entire mission ranging from 28.65 to 29.26 kg/m^3. In the first 100 m it varies from 28.6 to 28.9 kg/m^3 and it follows the salinity pattern. From 200 to 300 m density is between 28.9 and 29 kg/m^3 below 300 m to the bottom, the density increases to 29.2 kg/m^3.

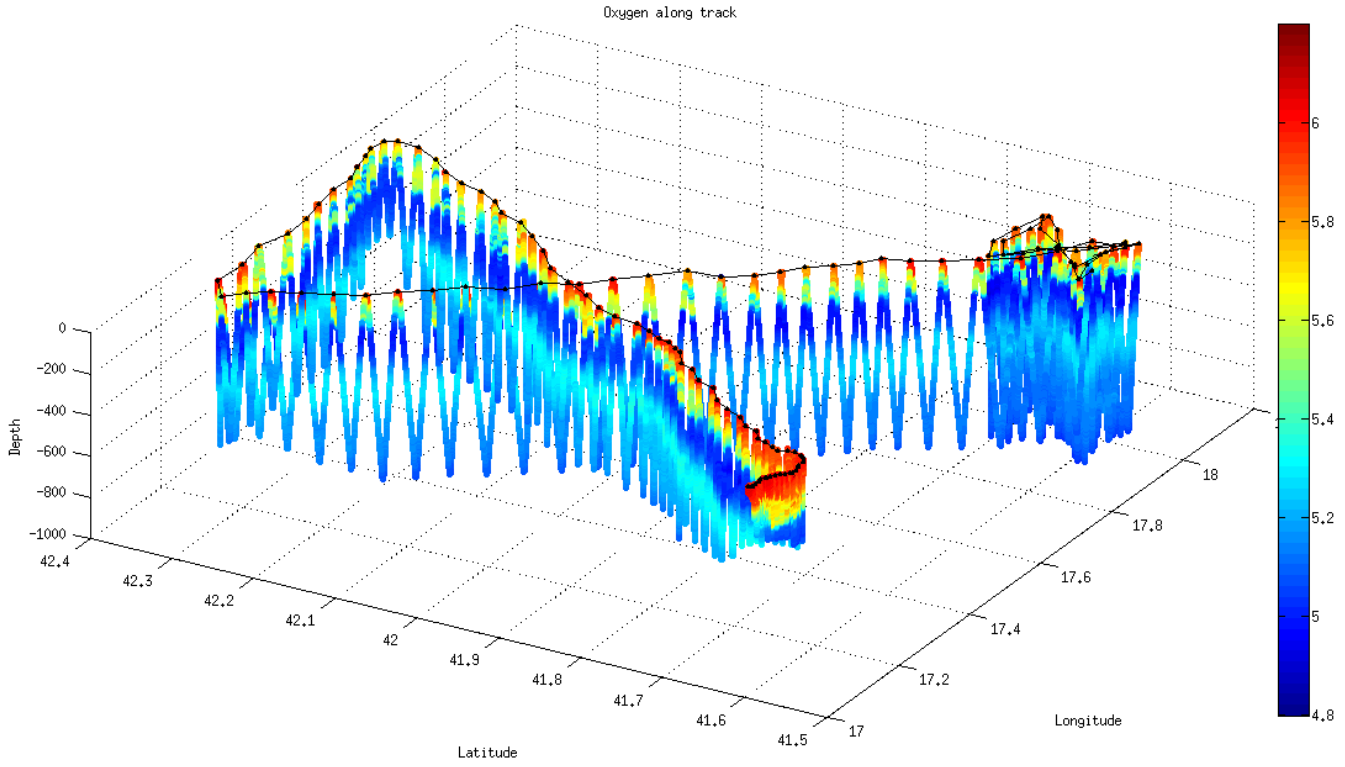


Fig. 5: Oxygen (ml/l) along track. The black line represents the surface trajectory of the glider.

During the mission the measured oxygen along the whole track ranges from 4.8 to 6.2 ml/l (Fig. 5). In the first 100 m, the dissolved oxygen is around 6.2 ml/l. The oxygen concentration decreases between 100 and 200 m to 6 - 5.4 ml/l. Below 200 m to almost 400 m, the oxygen concentration continues to decrease until 5 ml/l. Below this layer, the oxygen rises again to 5.4 ml/l, then it decreases again, reaching 5 ml/l below the 600 m.

4. First transect

The first transect (in black in Fig. 1) starts on 15/02/2014 at 14:24:24 UTC and finish on 17/02/2014 at 01:42:14 UTC. This part includes the shallowest dives, closer to the Italian coast and it is characterized by warm, light and less saline waters. In this transect, higher concentration of dissolved oxygen was found.

This first part of the glider path, covered an area influenced by the Italian coastal waters.

In the next figures (Fig. 6 to 9), each of the four analyzed parameters are plotted versus longitude.

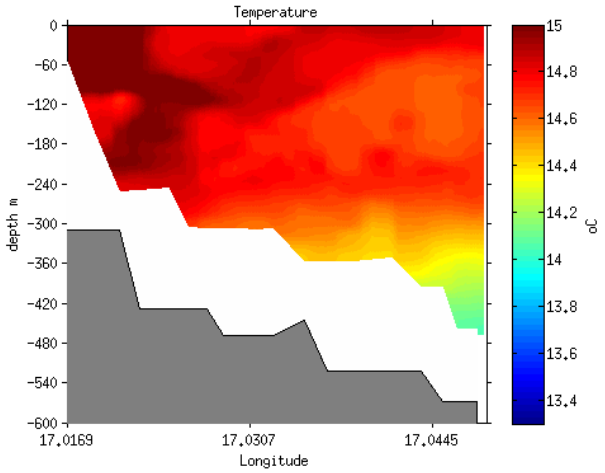


Fig. 6: Temperature plot, first transect.

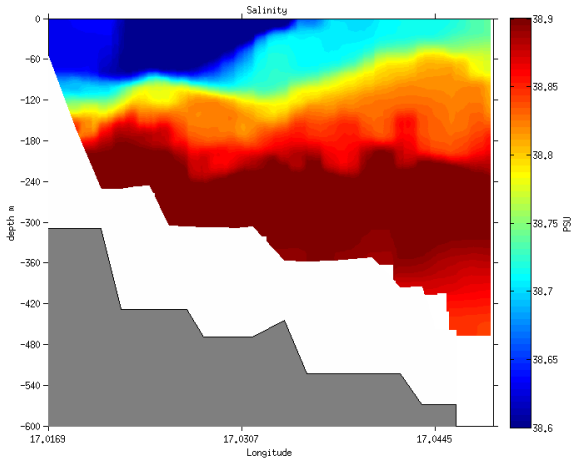


Fig. 7:Salinity plot, first transect.

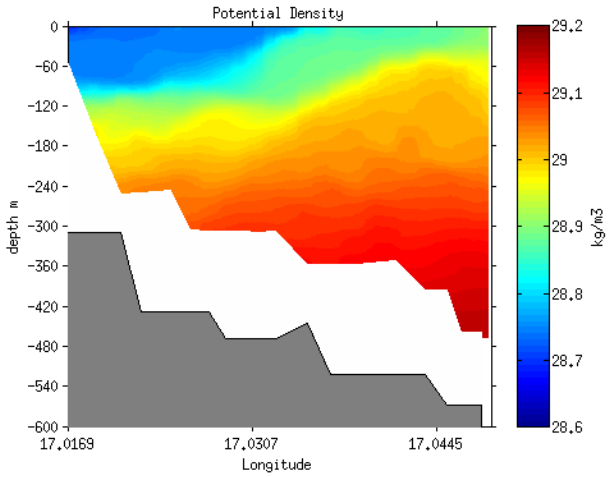


Fig. 8: Density plot, first transect.

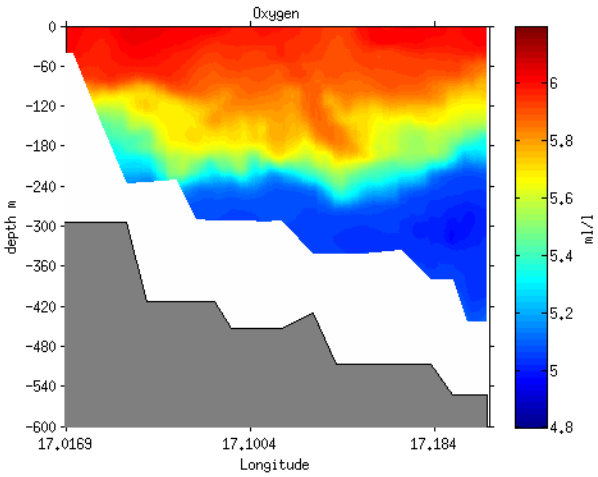


Fig. 9: Oxygen plots, first transect.

The warmest waters are located in the shallowest parts of this transect (Fig. 6). As the glider is heading eastward the temperature decreases. From 15 ^{o}C in the surface layer the temperature decreases to 14.2 ^{o}C close to 400 m.

Filaments of low salinity are visible in the shallowest waters (Fig. 7), with values around 38.65 PSU. Moving eastward the salinity increases to 38.75 PSU in the surface waters. From the surface down to 150 m, a layer of water with salinity that varies from 38.7 to 38.8 PSU (around in 150 m) is measured and, as we move deeper, salinity increases to 38.9 PSU, then it starts to decrease below 350 m.

Density in Fig. 8 follows the salinity pattern; it ranges from 28.65 kg/m^3 in the shallowest surface waters to 29.16 kg/m^3 as the glider is heading eastward and deeper.

From surface to the measured max depth of ~ 400 m, the oxygen concentration ranges from 5 to 6 ml/l (Fig. 9). The surface waters are characterized by high concentration of dissolved oxygen, around 6ml/l. From 100 to 240 m a meander shape layer where the oxygen varies from 5.3 ml/l – 5.8 ml/l is present. Below that, the oxygen concentration is decreases to around 4.8 - 5 ml/l.

5. Second transect

During this transect (in red in Fig. 1) the bathymetry increases and the glider explores deeper waters.

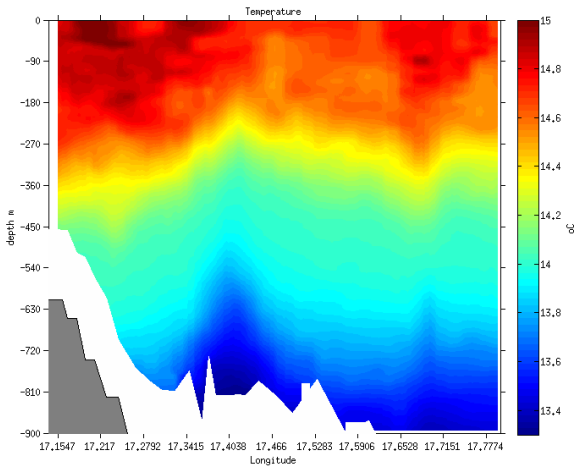


Fig. 10: Temperature plot, second transect.

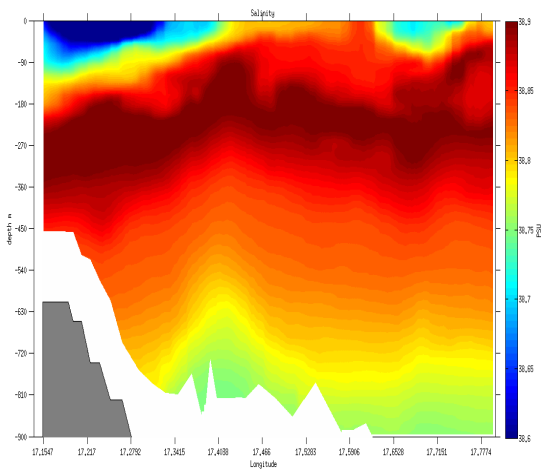


Fig. 11: Salinity plot, second transect.

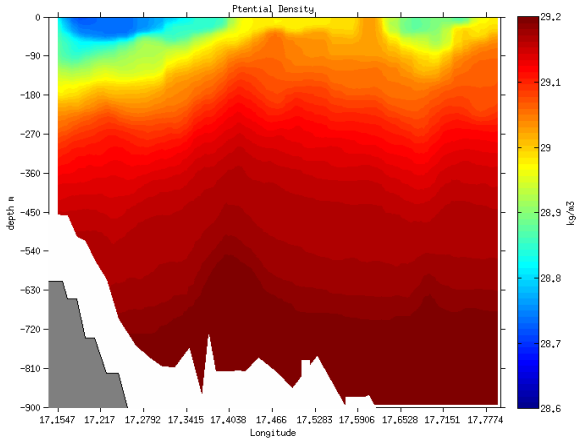


Fig. 12: Density plot, second transect.

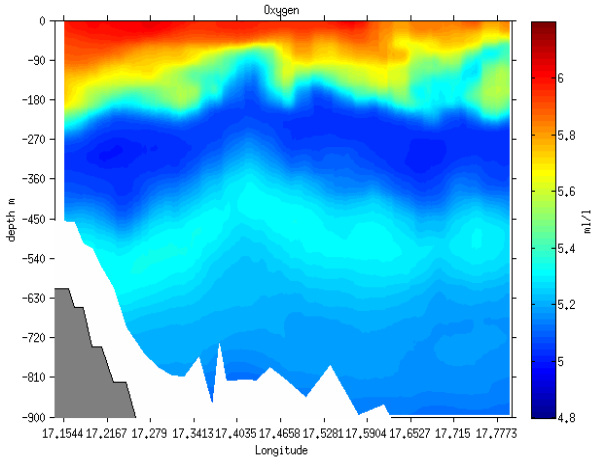


Fig. 13: Oxygen plot, second transect.

The temperature in this transect varies from 13.4 to 15 ^{o}C. Above 300 m the temperature ranges from 14.2 to 15 ^{o}C. Below this layer, the temperature decreases gradually to reach 13.4 ^{o}C at 900 m.

The glider sampled filaments of low salinity (~38.55 PSU) in the surface waters. A layer of higher salinity with a value around 38.88 PSU, is between 200 – 300 m. In the rest of the water column, the salinity ranges from 38.8 PSU near the surface and decreases gradually to 38.75 PSU in the bottom layers (~900 m).

The density (in Fig. 12) follows very well the salinity pattern. It ranges around 28.71 kg/m^3 near the surface and it increases gradually to 29.26 kg/m^3 in the deeper layers.

The surface waters are characterized by inhomogeneous concentration of dissolved oxygen (~ 5.3 – 6 ml/l). Below 150 m, a layer of low oxygen concentration is present (~ 4.9 – 5 ml/l). This layer extends down to 400 m. Below that depth, oxygen increases to 5.2 - 5.3 ml/l, and then it decreases again to around 5 ml/l at 900 m.

6. Third transect

During the third transect (in purple in Fig. 1), the glider moved in an almost straight line from east to west.

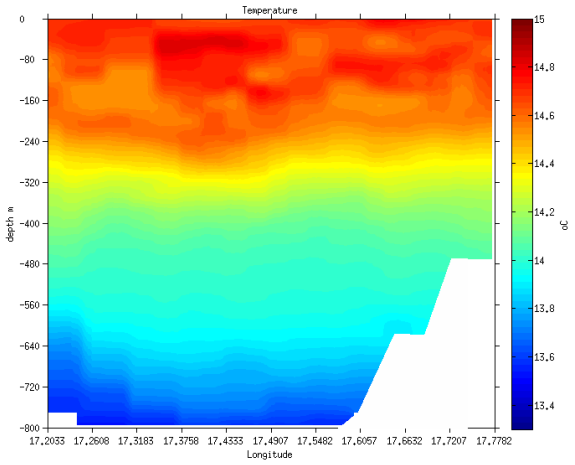


Fig. 14: Temperature plot, third transect.

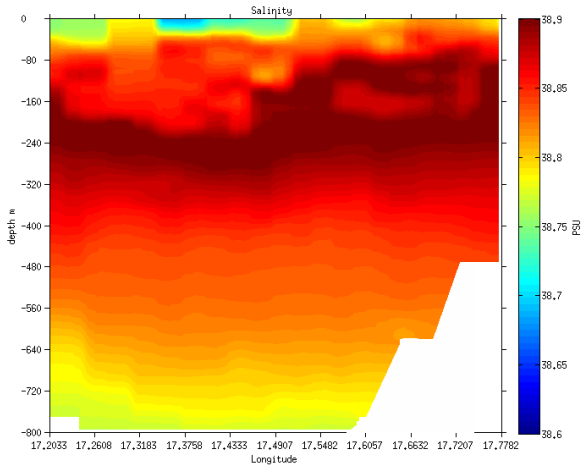


Fig. 15: Salinity plot, third transect.

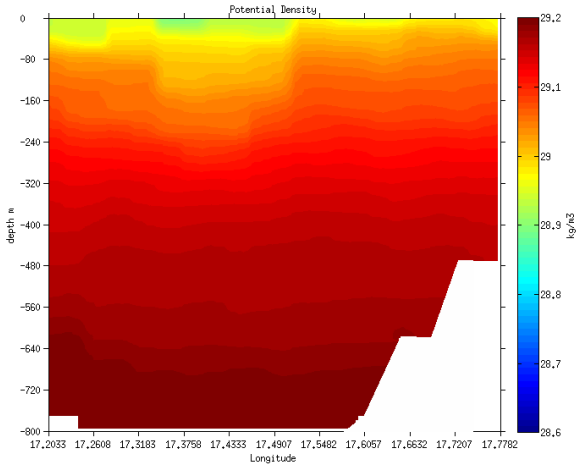


Fig. 16: Density plot, third transect.

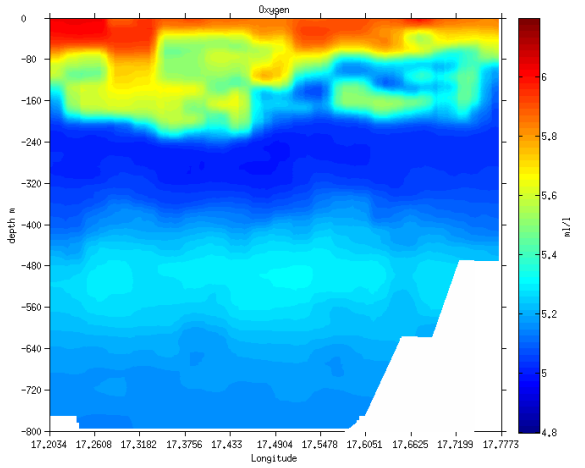


Fig. 17: Oxygen plot, third transect.

The temperature along this transect is around 14.8 ^{o}C at the surface and decreases to 13.6 ^{o}C in the bottom layers.

The salinity ranges between 38.85 and 38.75 PSU, with the exception of some surface fresher water masses, in which the salinity decreases to 38.7 PSU.

The density (Fig. 16) follows the salinity pattern and ranges from 29 to 29.2 kg/m^3, while at surface it reaches 28.9 kg/m^3.

The first 200 m are characterized by a inhomogeneous dissolved oxygen distribution. The glider measured oxygen from 5.1 to almost 6 ml/l at that layer. Below that layer, there is a low oxygen layer (~ 4.8 – 5 ml/l). This layer extends until 400m. Then, oxygen increases to almost 5.3 ml/l.

7. Forth transect

This transect was oriented along the main axes of the Adriatic Sea (NW to SE) and it finished in the middle of the SAP (blue part in Fig. 1).

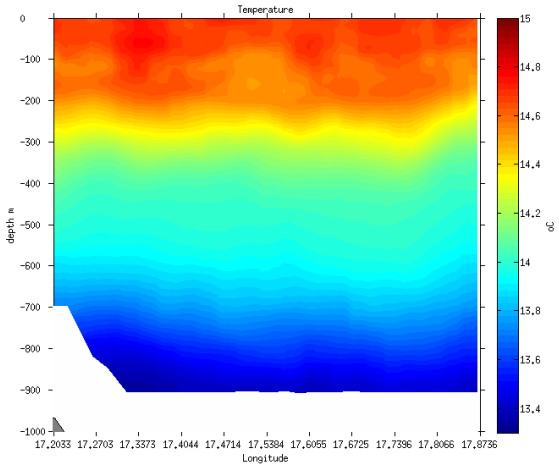


Fig. 18: Temperature plot, fourth transect.

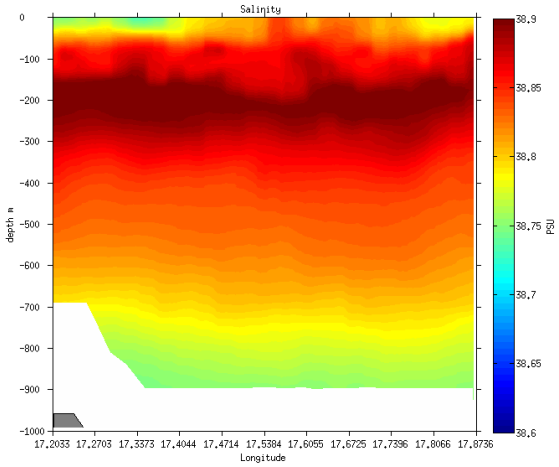


Fig. 19: Salinity plot, fourth transect.

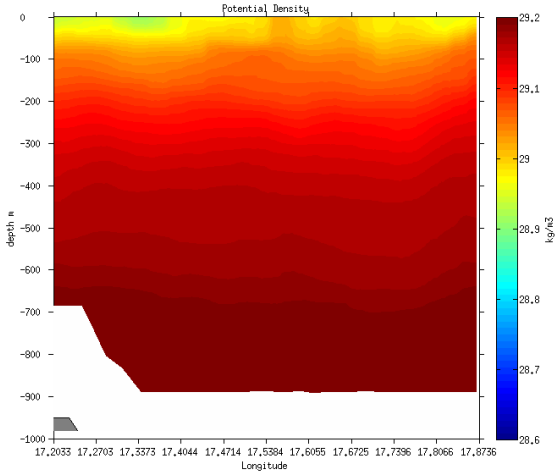


Fig. 20: Density plot, fourth transect.

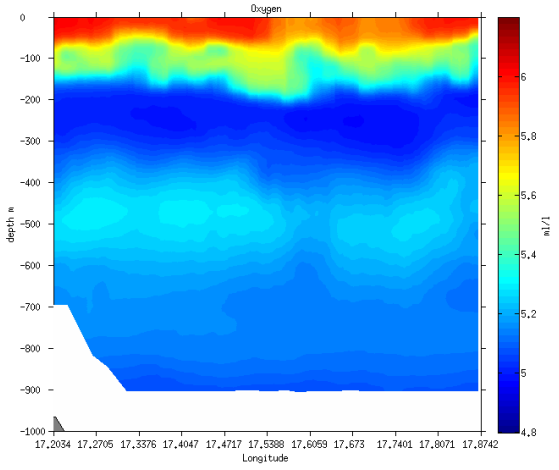


Fig. 21: Oxygen plot, fourth transect.

The temperature maximum (Fig. 18) is 14.8 ºC and it is recorded at the surface. From the surface to 300 m, the temperature ranges from 14.8 to 14.3 ºC. Below 300 m it falls to 14 ºC near 600 m and it reaches 13.4 ºC in the deeper layers.

The salinity maximum is 38.9 PSU and it is found around 200 m depth. In the deep layers falls to almost 38.75 PSU.

The easternmost surface waters are lighter with respect to the rest. As the glider moves toward west and it goes deeper, density increases (Fig. 20).

The oxygen (Fig. 21) has its maximum concentration in the first 100 m and then it decreases in the deep layers, except for a slightly more oxygenated water layer between 400 m and 600 m.

8. 'Butterfly' path

The “butterfly” path (see Fig. 1) started on 02/28/2014 at 16:06:53 UTC and finished at the end of the mission. It was separated in 4 main subtransects (Fig. 22) that were repeated 2 or 3 times each (Figs. 23 to 26). Thus, these subtransects are investigated in order to analyze the possible temporal variability.

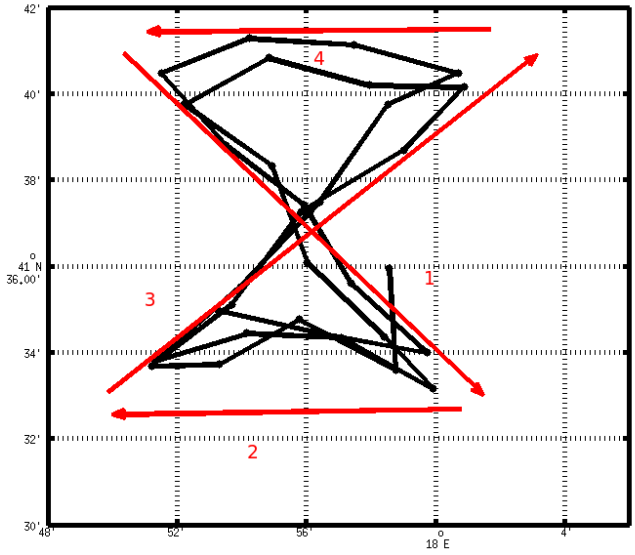
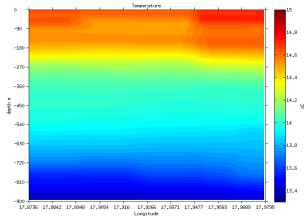


Fig. 22: The 'butterfly' path.



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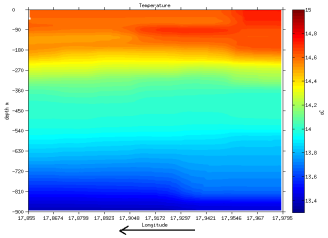

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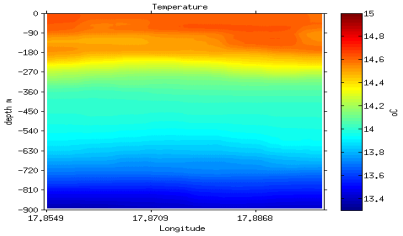

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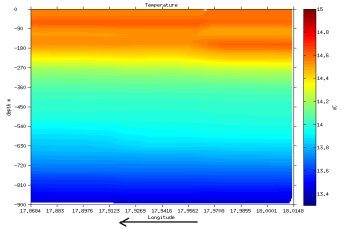

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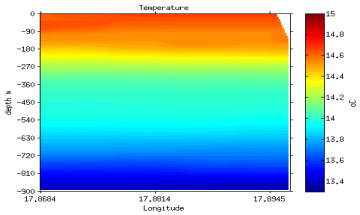

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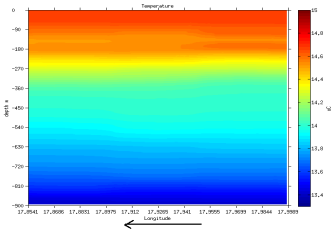

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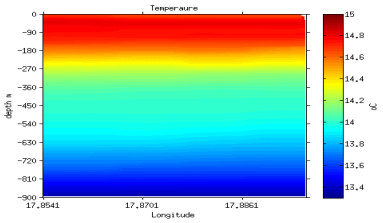

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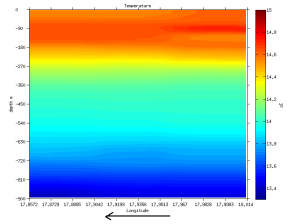

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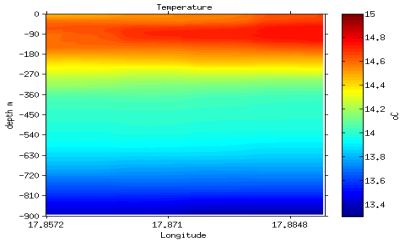

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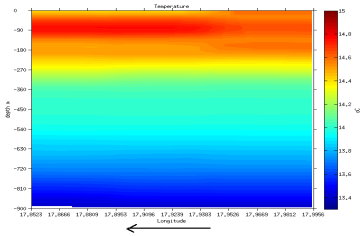
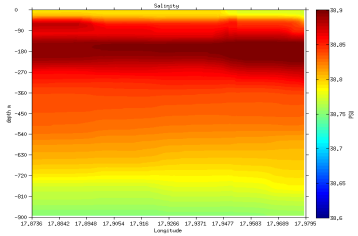


Trans.-10

Fig. 23: Temperature plots of the 10 subtransects. The black arrow under the plots shows the direction of the glider. Temperature ranges from 14.7 °C at the surface, to 13.3 °C in the bottom layers. No significant variability was recorded.



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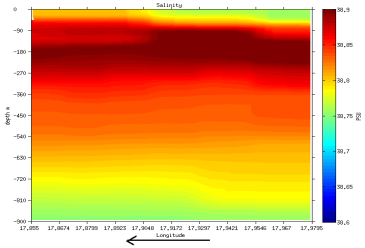

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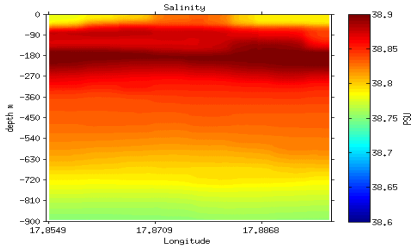

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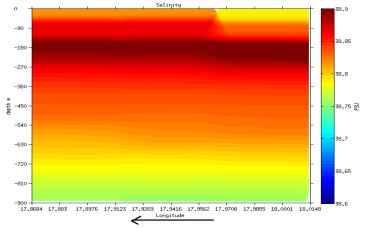

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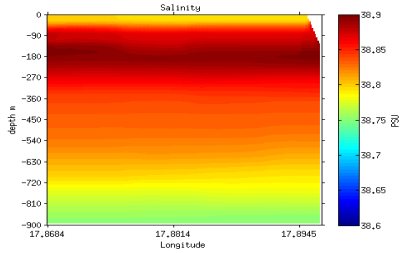
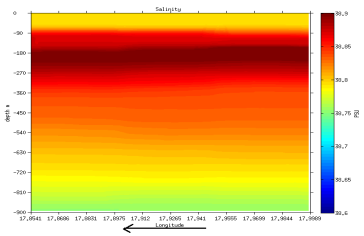
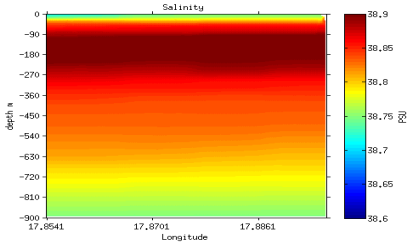


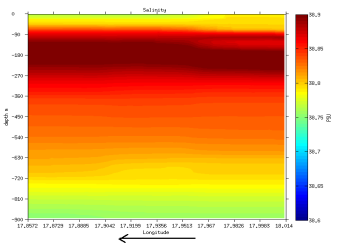
Trans.-5



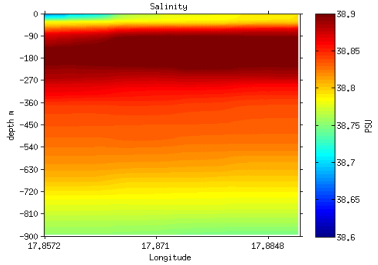
Trans.-6



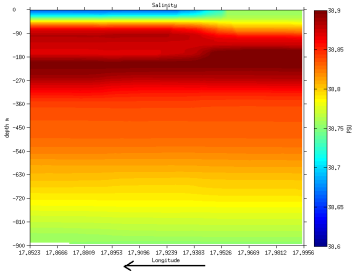
Trans.-7



Trans.-8

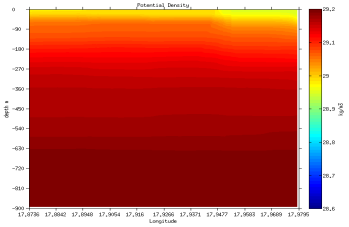


Trans.-9

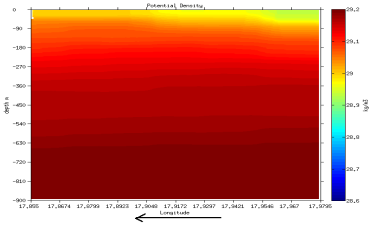


Trans.-10

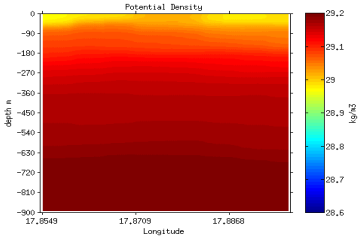
Fig. 24: Salinity plots of the subtransects during the 'butterfly'. Differences in the surface salinity are present, these are more evident in the second subtransect (trans.2 and trans.10), when the surface salinity values decrease from 38.92 to almost 38.58 PSU. There is no significant variation at the deeper layers.



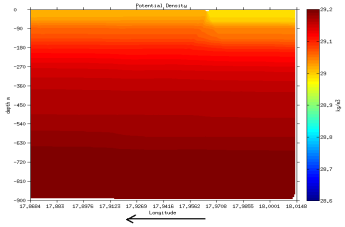
Trans. -1



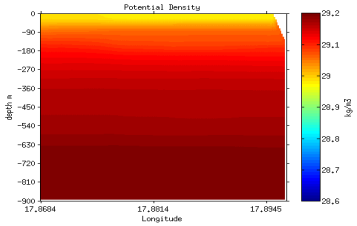
Trans. -2



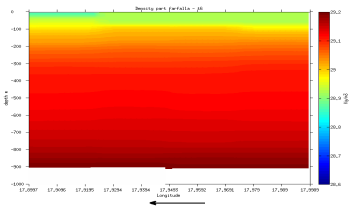
Trans. -3



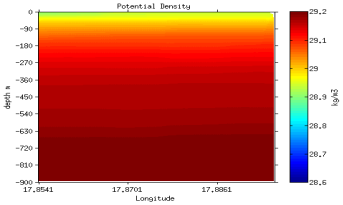
Trans. -4



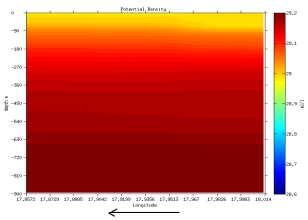
Trans. -5



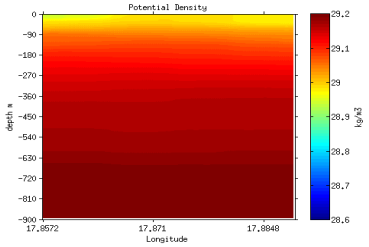
Trans. -6



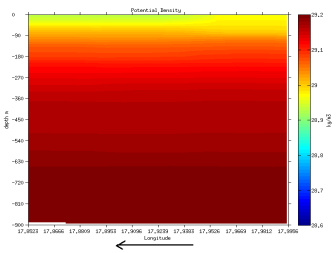
Trans. -7



Trans. -8

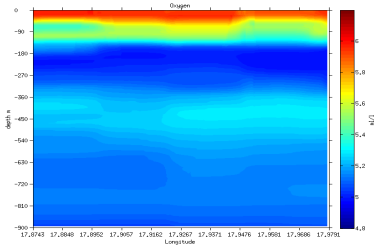


Trans. -9

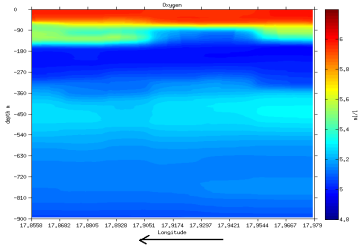


Trans. -10

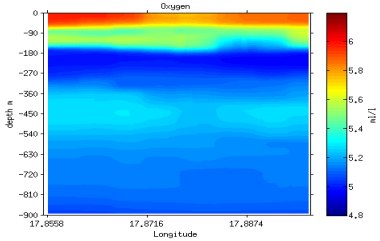
Fig. 25: Density plots of the subtransects during the 'butterfly'. Density follows the salinity pattern and ranges from 28.86 to 29.25 kg/m^3 .



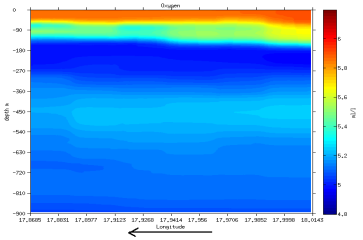
Trans. -1



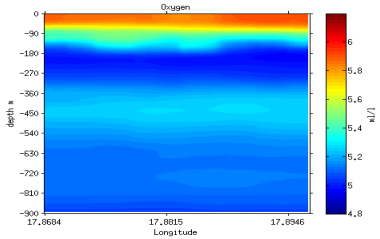
Trans. -2



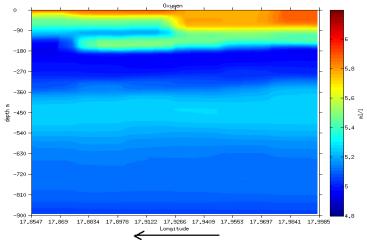
Trans. -3



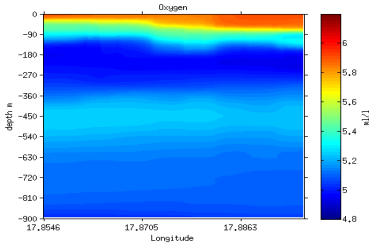
Trans. -4



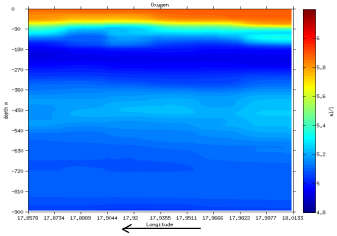
Trans. -5



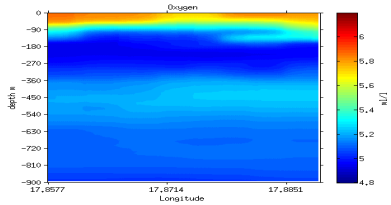
Trans. -6



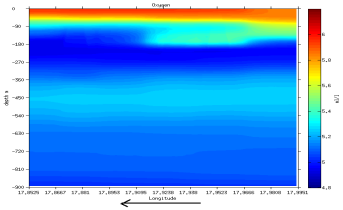
Trans. -7



Trans. -8



Trans. -9



Trans. -10

Fig. 26: Oxygen plots of the subtransects during the 'butterfly'. Oxygen concentration varies in space and in time. Below 100 m all transects have a similar profile. The first 100 m displays high temporal variability.

9. Comparison with E2M3A buoy and float data

The moored E2M3A buoy is located at the latitude and longitude of 41.836 ^{o}N, 17.756 ^{o}E at a point where the bathymetry is about 1200 m (Fig. 30). The deep-sea mooring is equipped with CT and biochemical sensors. It takes measurements at specific depths (15 m, 365 m, 570 m, 780 m, 900 m and 1000 m) every 1 or 3 hours (depending on the depth).

Data from the buoy are compared with the glider data during the 'butterfly' path.

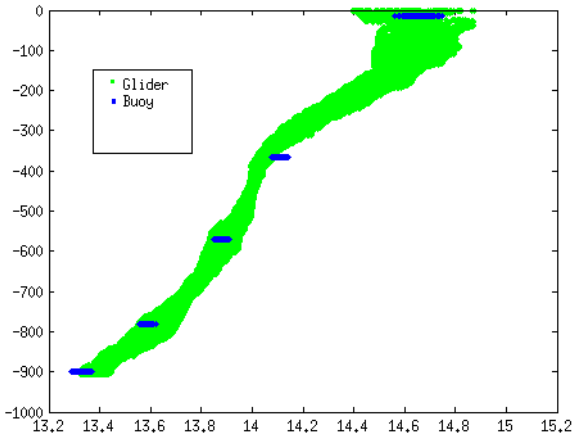


Fig. 27: Temperature comparison between buoy data (in blue) and glider data during butterfly path (in red).

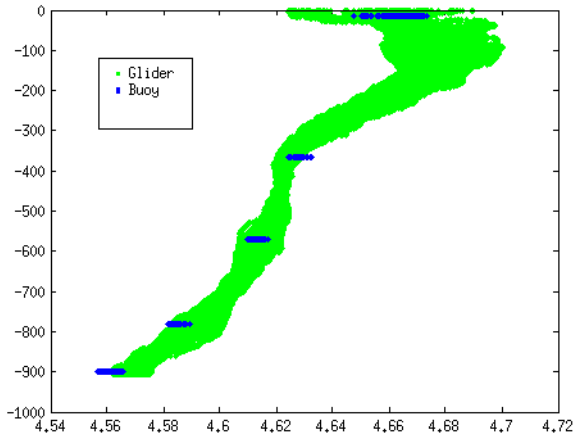


Fig. 28: Conductivity comparison between buoy data (in blue) and glider data during butterfly path (in red).

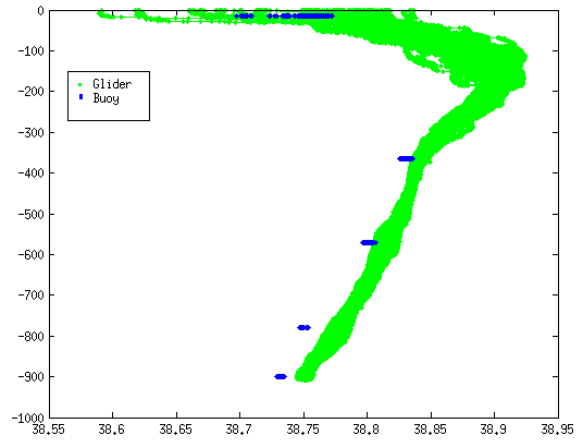


Fig. 29: Salinity comparison between buoy data (in blue) and glider data during butterfly path (in red).

The data were compared to access the spatial variability, measured by the glider, relative to a fixed point such as the E2M3A buoy. The results are depicted in Figs. 27 to 29. There are very small differences in temperature and conductivity between buoy and glider data. Surface glider salinity (15 m) is in a good agreement with the salinity measured by the buoy, while the differences at the deep layers (deeper than 570 m) are increasing (around 0.02 PSU).

The glider data were also compared with data the from a float, that was in the area during the same period. The float data were downloaded from the Coriolis Data Centre. Several floats where inside the area of interest, but only four profiles of the float with WMO number 6901822, overlapped both temporally and spatially with the CONVEX14 mission. Fig. 30 depicts the glider transect and the float profiles (stars symbols) that where used in the comparison.

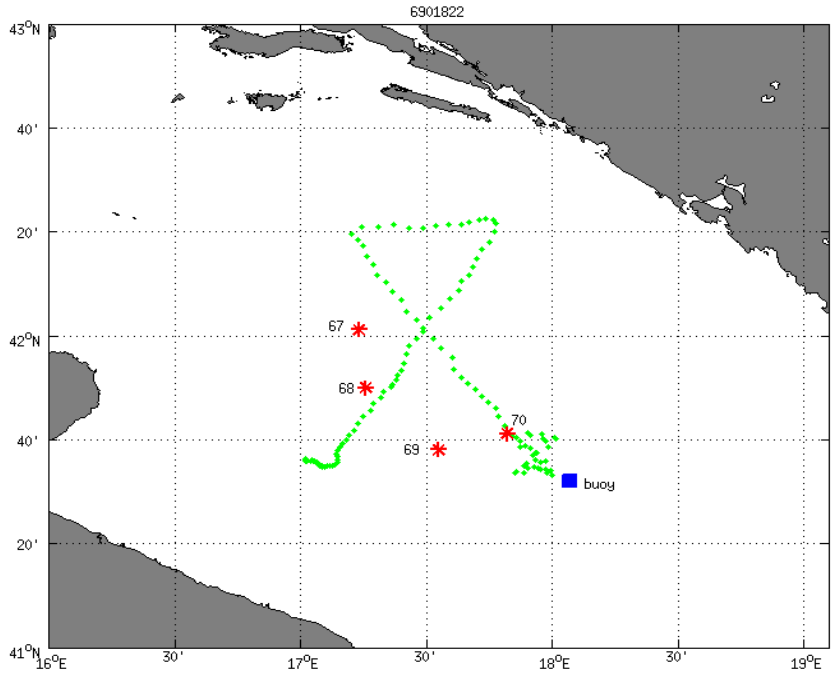


Fig. 30: The glider trajectory is in green, the float profiles that were used are depicted in red (the number is referred to the profile number) and the buoy in blue.

Figs. 31 to 33 depict the comparison between glider (in green), float (in red), for temperature, conductivity and salinity for the same time period.

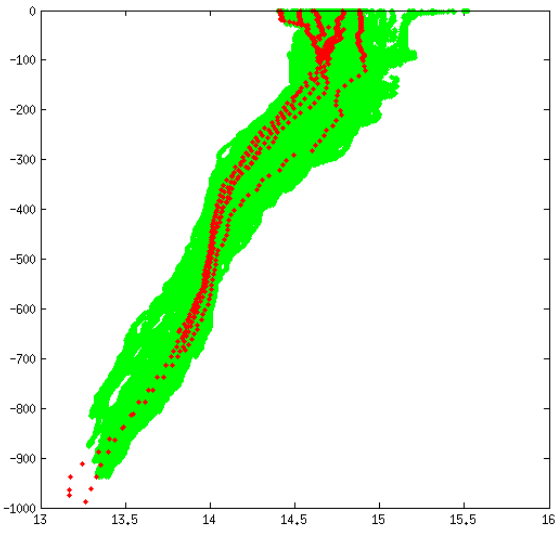


Fig. 31: Temperature comparison from all the data between glider (in green) and float (in red).

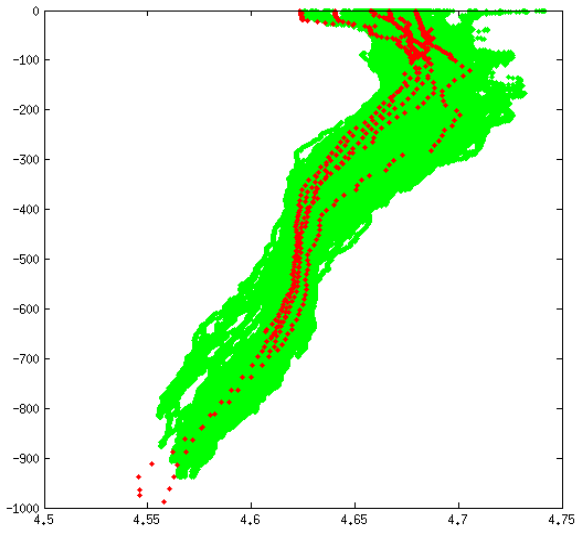


Fig. 32: Conductivity comparison from all the data between glider (in green) and float (in red).

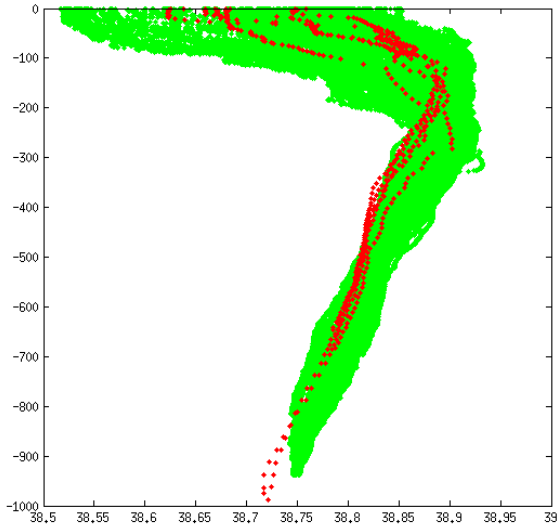


Fig. 33: Salinity comparison from all the data between glider (in green) and float (in red).

There was a notably good agreement between float profiles and glider in temperature, conductivity and salinity at all depths.

10. Conclusions

The aim of the mission was to monitor the Adriatic Dense Water (ADW). The forcing situation that can trigger the formation of the ADW is the particularly intense cooling of the surface water related to the the prolonged cold Bora wind. Unfortunately, probably due to the 'mild' winter, no strong Bora wind and higher temperature than the climatology, the ADW was not observed in winter 2014.

During the CONVEX14 mission we measured deep waters with density around 29.2 kg/m^3, corresponding to waters with temperature around 13.3 ^{o}C (as shown in Fig. 2) and salinity in 38.75 PSU – 38.8 PSU and which probably represent the Adriatic Bottom Water (ABW), a dense water mass formed in the southern Adriatic that flows south and exits into the Ionian Sea via the Otranto Strait and spreads over the Eastern Mediterranean bottom layer (Gacic et al, 1996).

The glider was steered in a 'Butterfly' shaped path close to the E2M3A buoy, in order to estimate the spatial variability of temperature and salinity at several depths, relative to the E2M3A buoy. The data of the buoy were compared with the glider and it was found that temperature is more stable spatially and it is not changing much as we move away from the buoy. Salinity, however, shows higher spatial variability in all the water column.

The glider data were compared also with data from float profiles. Float and glider comparison shows a very good agreement.

11. Acknowledgement

We would like to thank Manuel Bensi and Vanessa Cardin for providing us with the E2M3A Buoy data, needed for the comparison.

12. References

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Gacic, M., Manca, B.B., Mosetti, R., Scarazzato P., and Viezzoli, D., 1998: Deep Water Formation Experiment in the Adriatic Sea is being repeated again this Year, http://doga.ogs.trieste.it/doga/oce/deep_water/mtpnews1.html, Istituto Nazionale di Oceanografia e di Geofisica Sperimentale.

Gerin, R. and Kokkini, Z., 2015: Conductivity data measured by a cracked conductivity cell: the case of Convex 14 SeaGlider experiment. Technical report 2015/57 sez. OCE 18 MAOS.

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